

Contribution to HiLiftPW-3

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Summary of cases completed: TAU, SA-neg



Case	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1a (full gap)	no	no	
1b (full gap w adaption)	no	no	
1c (partial seal)	no	no	
1d (partial seal w adaption)	no	no	
Other			

Case	Polar, Fully turb	Polar, specified transition	Polar, w transition prediction	Other
2a (no nacelle)	yes	no	no	B-JSM_UnstrMixed_SOLAR ARA-SOLAR
2b (no nacelle w adaption)	no	no	no	
2c (with nacelle)	yes	no	no	B-JSM_UnstrMixed_SOLAR ARA-SOLAR
2d (with nacelle w adaption)	no	no	no	
Other				

Case	2D Verification study	Other
3	no	
Other		

Mesh generator

- Solar mesher, principally developed by ARA and BAE Systems.
- Quad-dominant surface mesh using advancing-front paving algorithm.
- Hex-dominant advancing-layer near-field mesh; tetrahedral far-field mesh using Delaunay.
- Source-driven mesh spacing, generated through combination of templates and interactively.
- High level of mesh anisotropy possible, driven by functionality of sources.
- Shaw J. A., Stokes S. and Lucking M. A., “The rapid and robust generation of efficient hybrid grids for RANS simulations over complete aircraft”, *Int. J. for Numerical Methods in Fluids*, 43:785-821, 2003.

Flow solver

- TAU, developed by DLR.
- Vertex-based, finite volume, second order. Central scheme with scalar dissipation.
- Backward Euler time-stepping with 3w multigrid, 80 cores.
- SA-neg turbulence model for all cases.
- Schwamborn D., Gerhold T and Heinrich R., “The DLR TAU-code: recent applications in research and industry”, *European Conference on Computational Fluid Dynamics*, 2006.

Brief overview of grid system(s)



Grid System	Case(s)	If committee grid, report any problems/issues If user grid, reason for generating grid system
Committee (B-JSM_UnstrMixed_DLR_SOLAR)	2a, 2c	No problems
User (Hybrid - SOLAR)	2a, 2c	Generated grid system because... see below...

- ARA has a desire to ensure all of its CFD processes are
 - the best they can be
 - fit for purpose
 - industrially robust
- HLPW3 is an opportunity for ARA to benchmark high-lift best practices.
- Any compliance with the workshop meshing guidelines is coincidental.
- No tuning or mesh refinement exercise in order to get the best possible comparison with experiment data.

Brief overview of grid system(s)



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User (Hybrid - SOLAR)	2a, 2c	Generated grid system because... see below...

- ARA mesh details
 - Hemispherical domain, farfield at 55m radius. ($>100 C_{ref}$)
 - First cell height 0.0067mm, 2 layers of equal height normal to the wall, growth rate of 1.3.
 - 6 cells across all trailing edges
 - Spanwise cell spacing varies from $\sim 0.2\%$ to $\sim 0.55\%$ semispan (tip to root respectively)
 - Chordwise cell spacing varies across the chord, $\sim 0.1\%$ local chord at Leading edges.
- Suitability of JSM Geometry and Committee Mesh:
 - Import of STEP geometry files to CADfix was straightforward – no fundamental CAD errors.
 - Some minor CAD modifications to assist with SOLAR meshing (no shape simplifications).
 - Committee SOLAR meshes were perfect for TAU, as expected, but the nacelle-pylon case is one of the largest meshes that ARA has handled!
 - For the most part convergence was excellent with both the committee and ARA grids that were used.

Brief overview of JSM grids

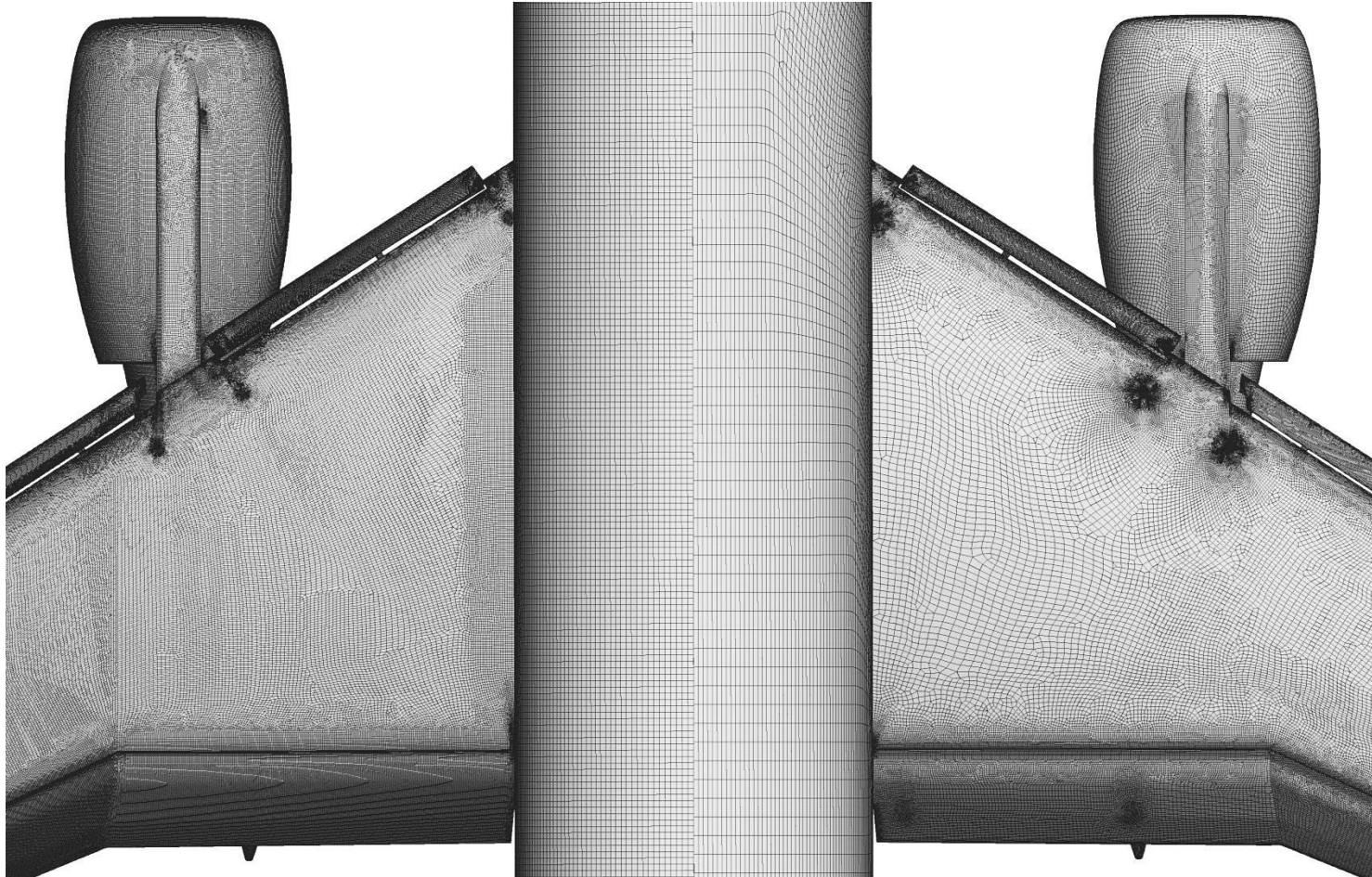


DLR-SOLAR

Points : 125,621,876
Elements : 206,920,972

ARA-SOLAR

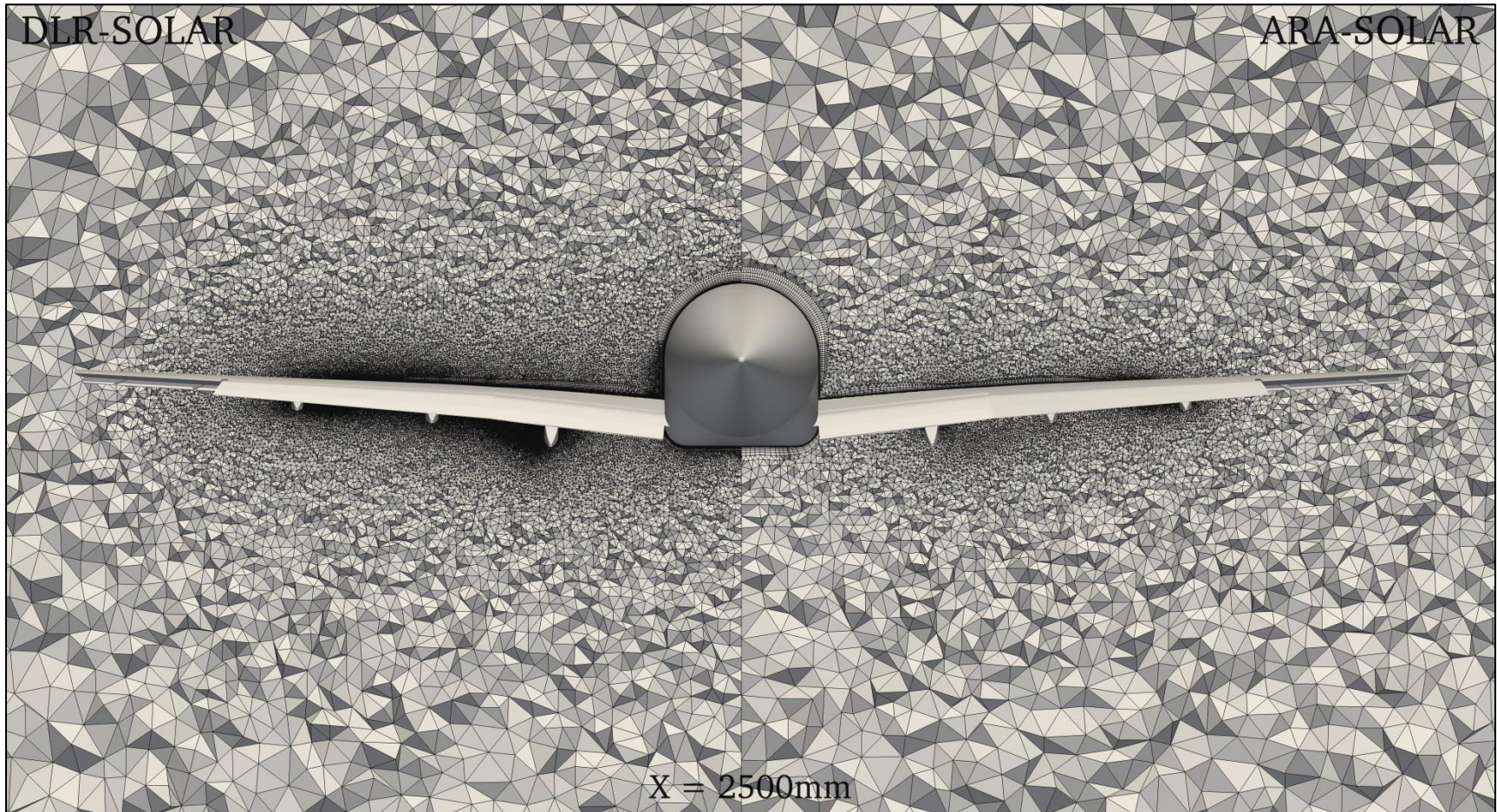
Points : 30,974,425
Elements : 69,559,533



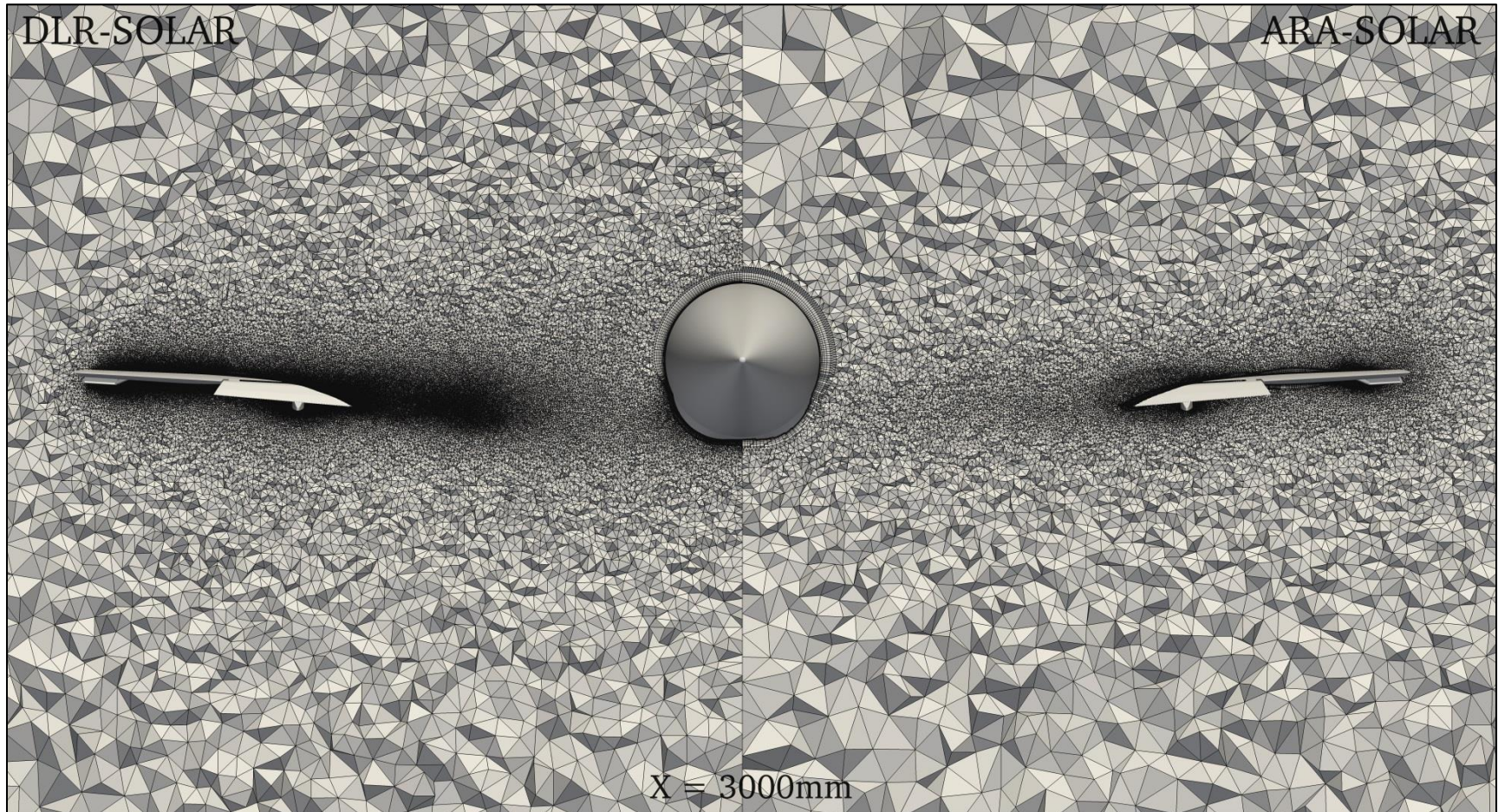
Brief overview of JSM grids



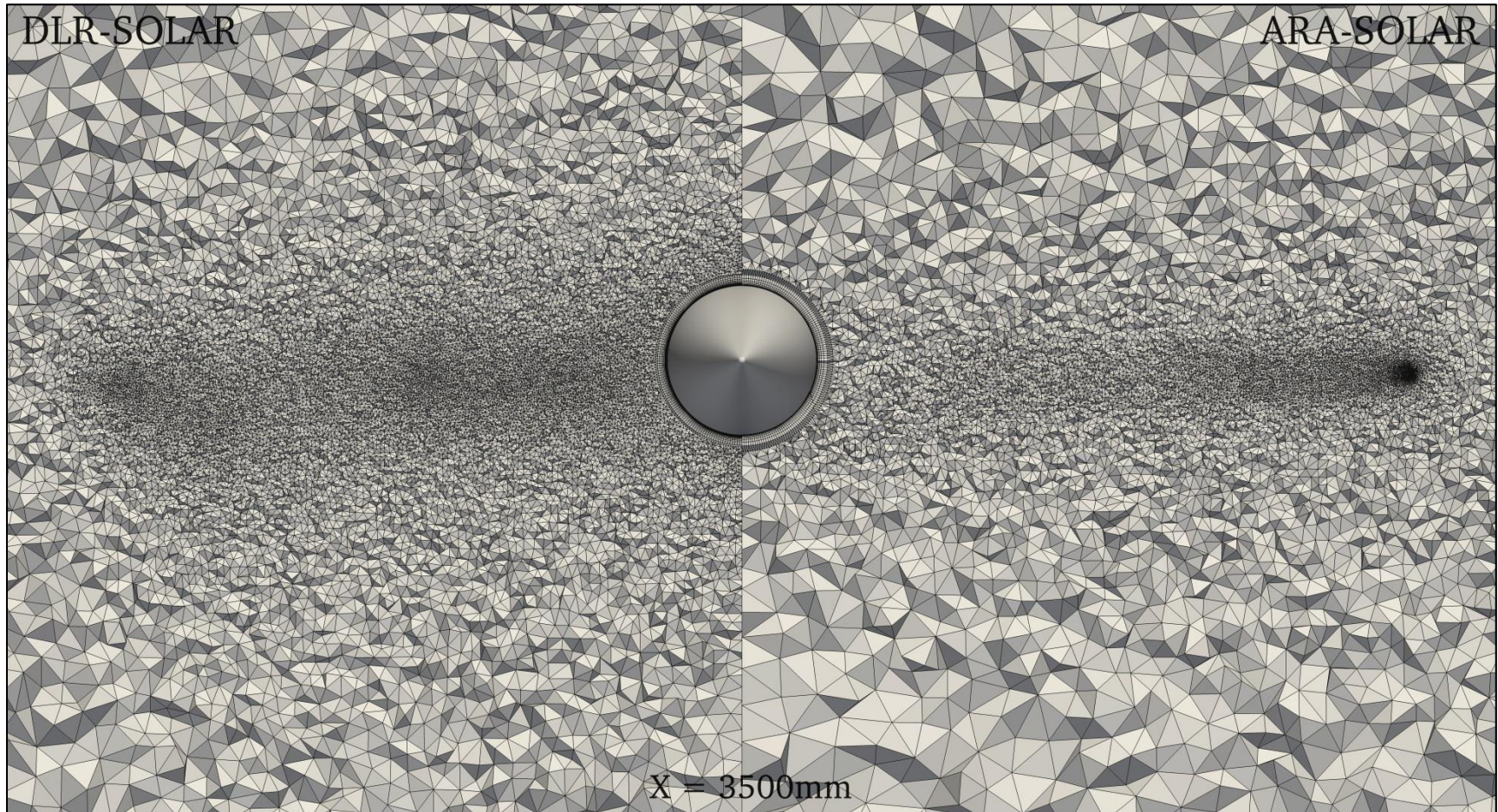
Brief overview of JSM grids



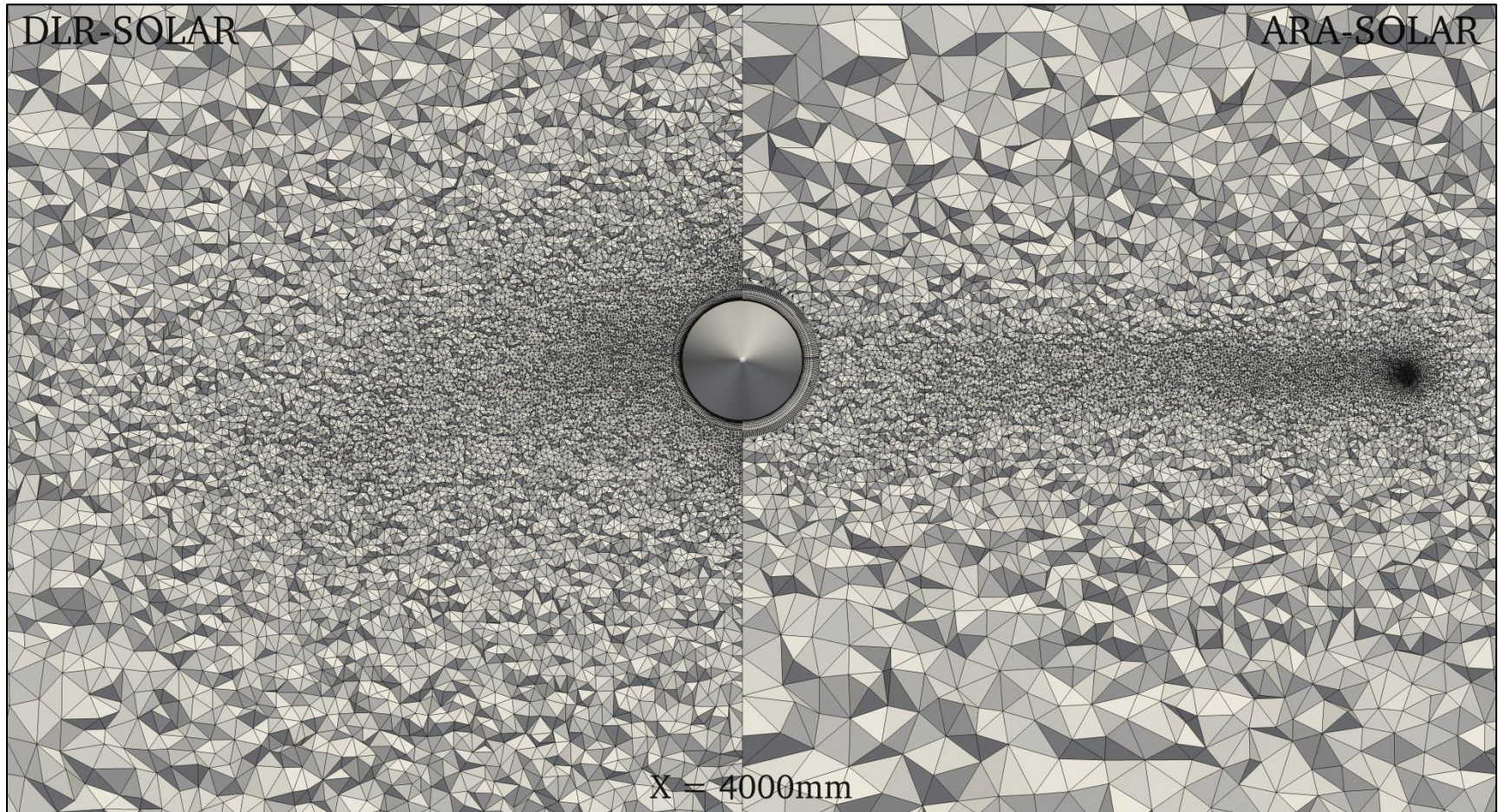
Brief overview of JSM grids



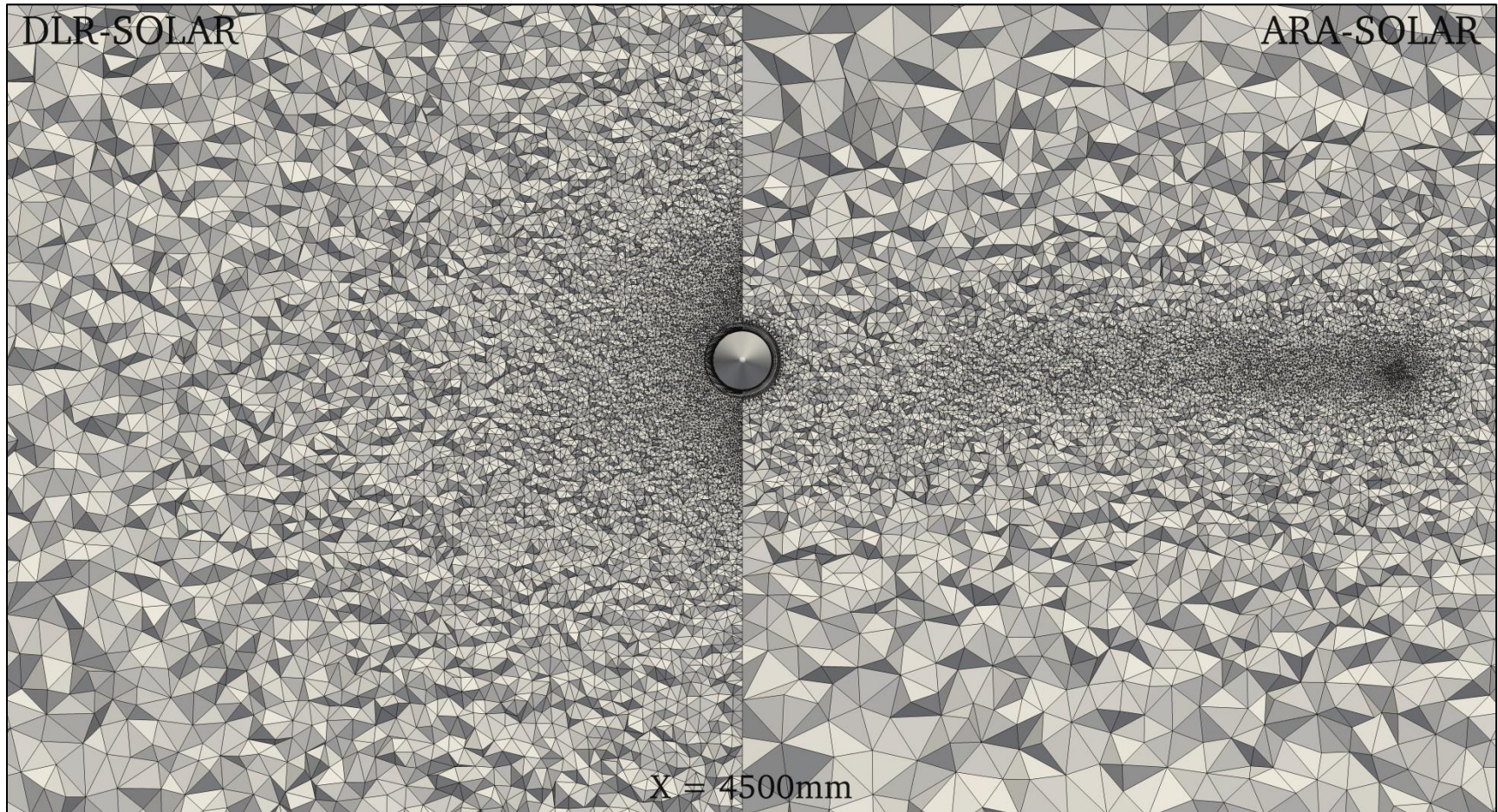
Brief overview of JSM grids



Brief overview of JSM grids

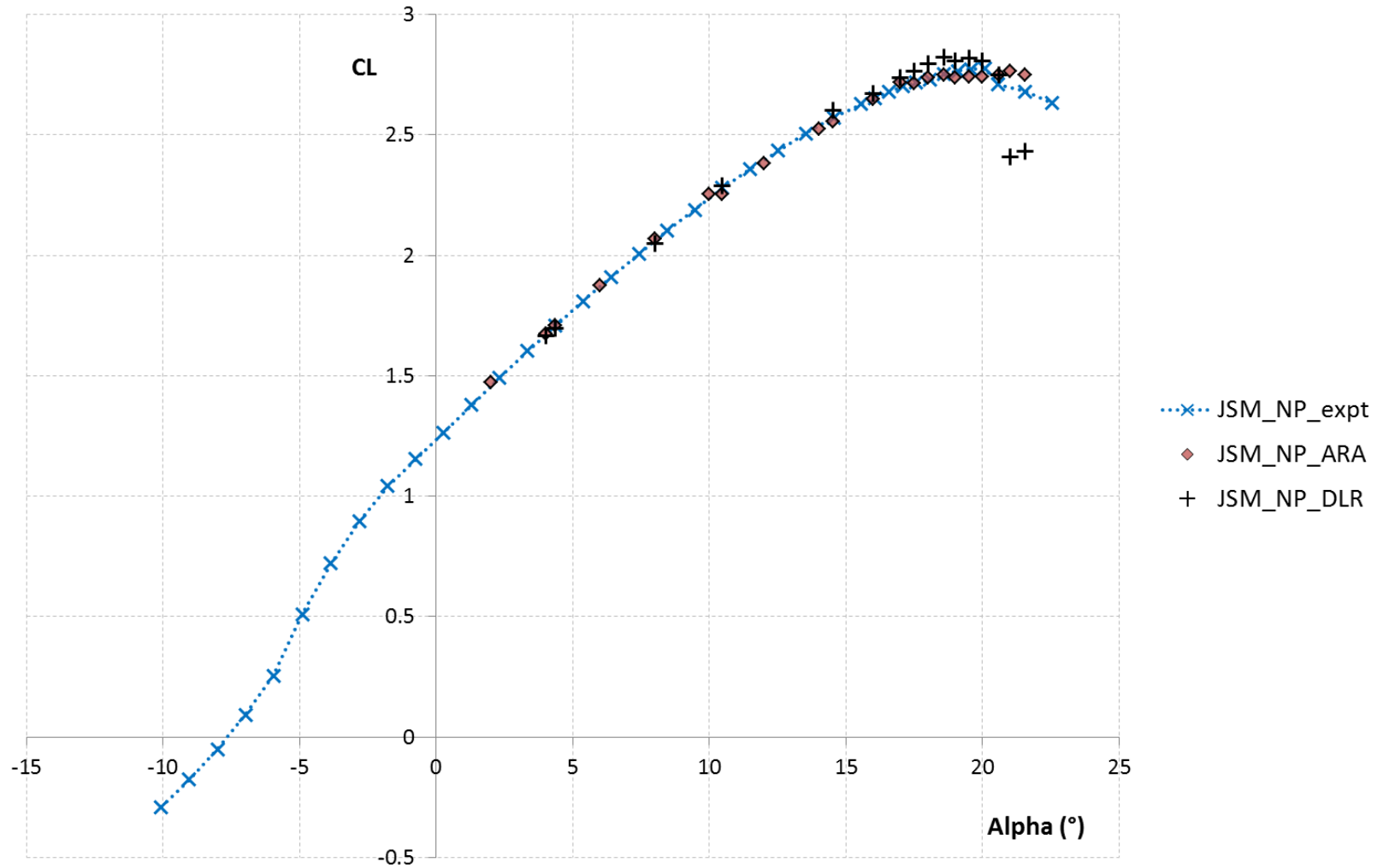


Brief overview of JSM grids



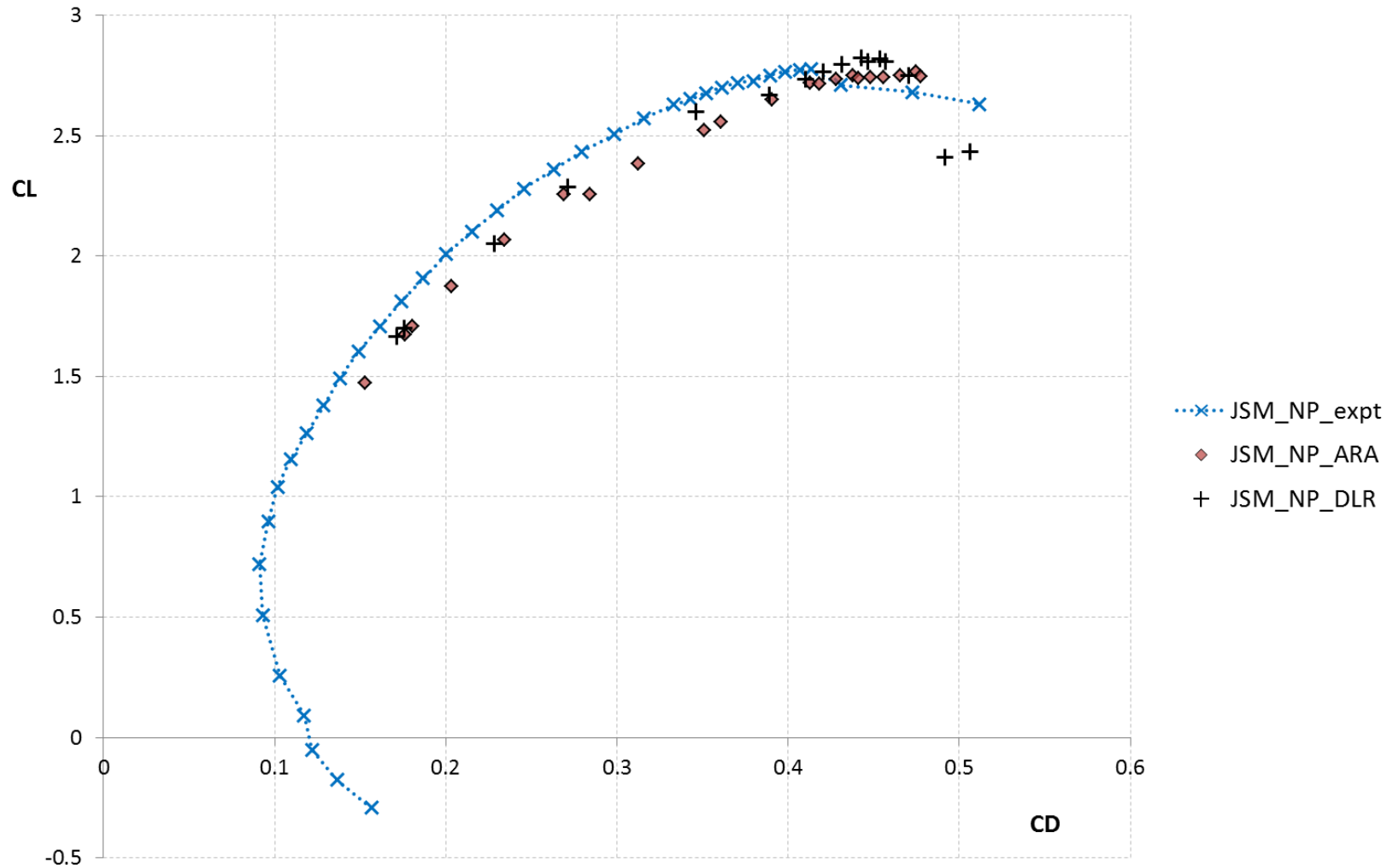
JSM with Nacelle-Pylon:

Variation of lift with alpha



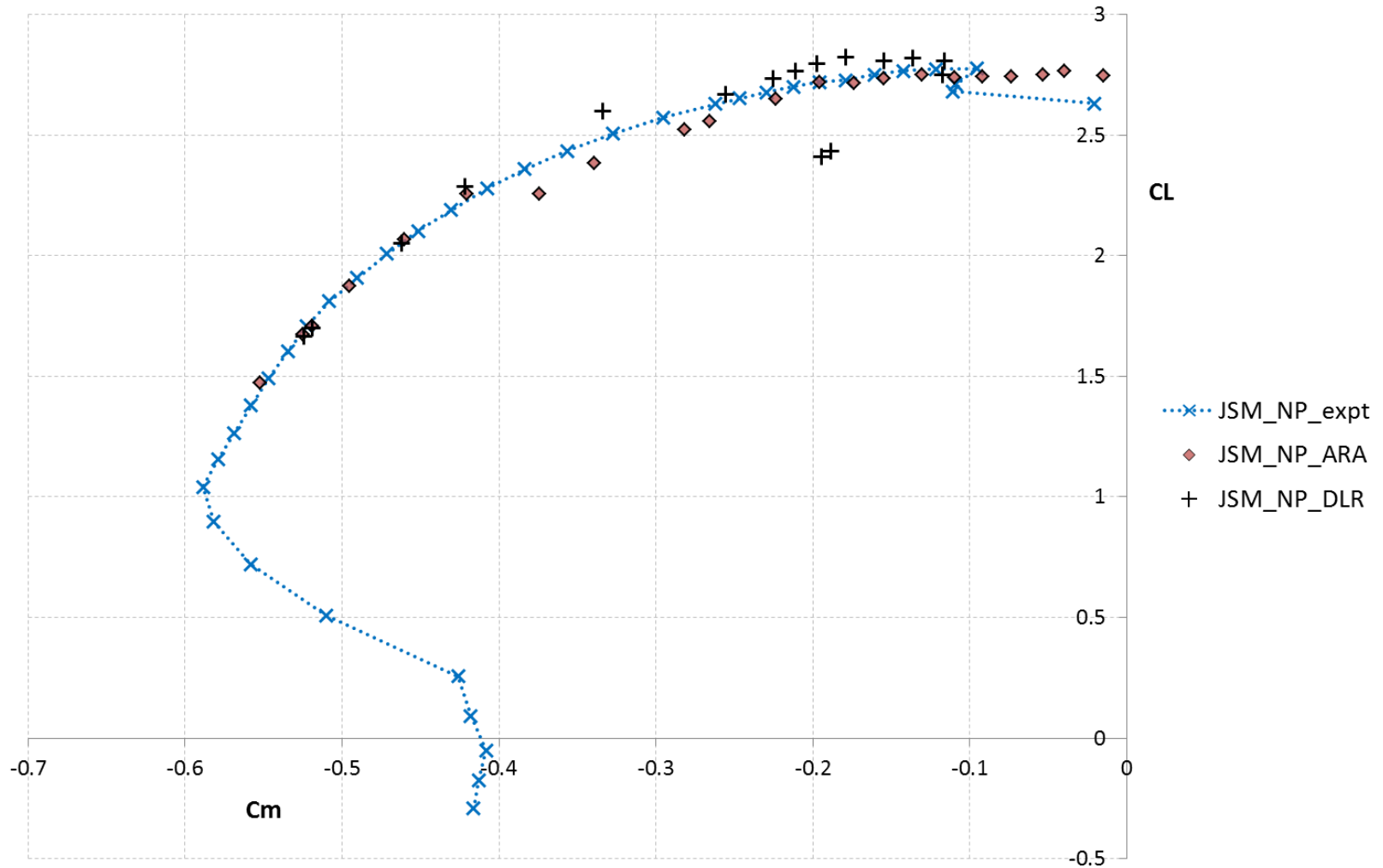
JSM with Nacelle-Pylon:

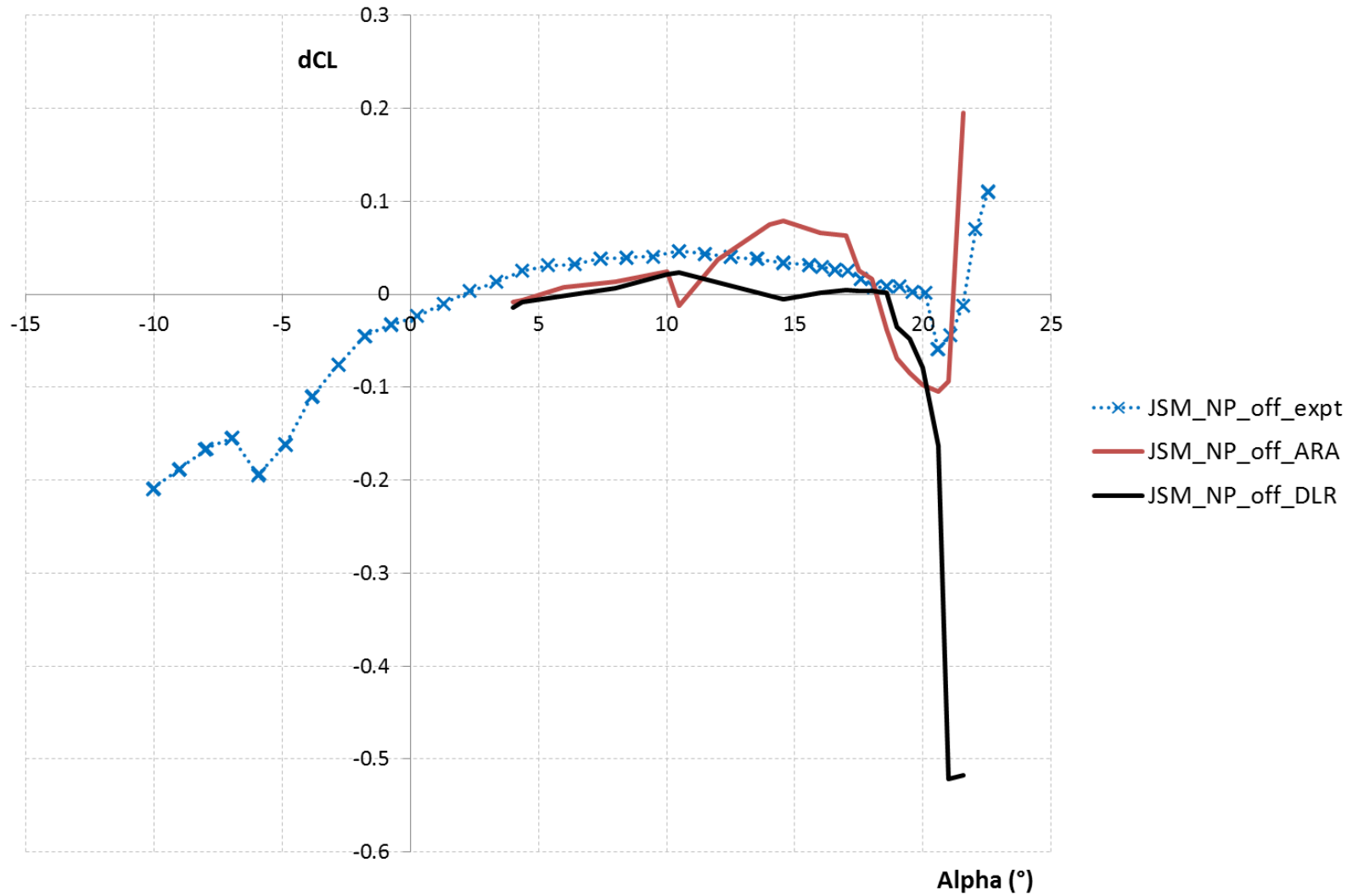
Variation of drag with lift

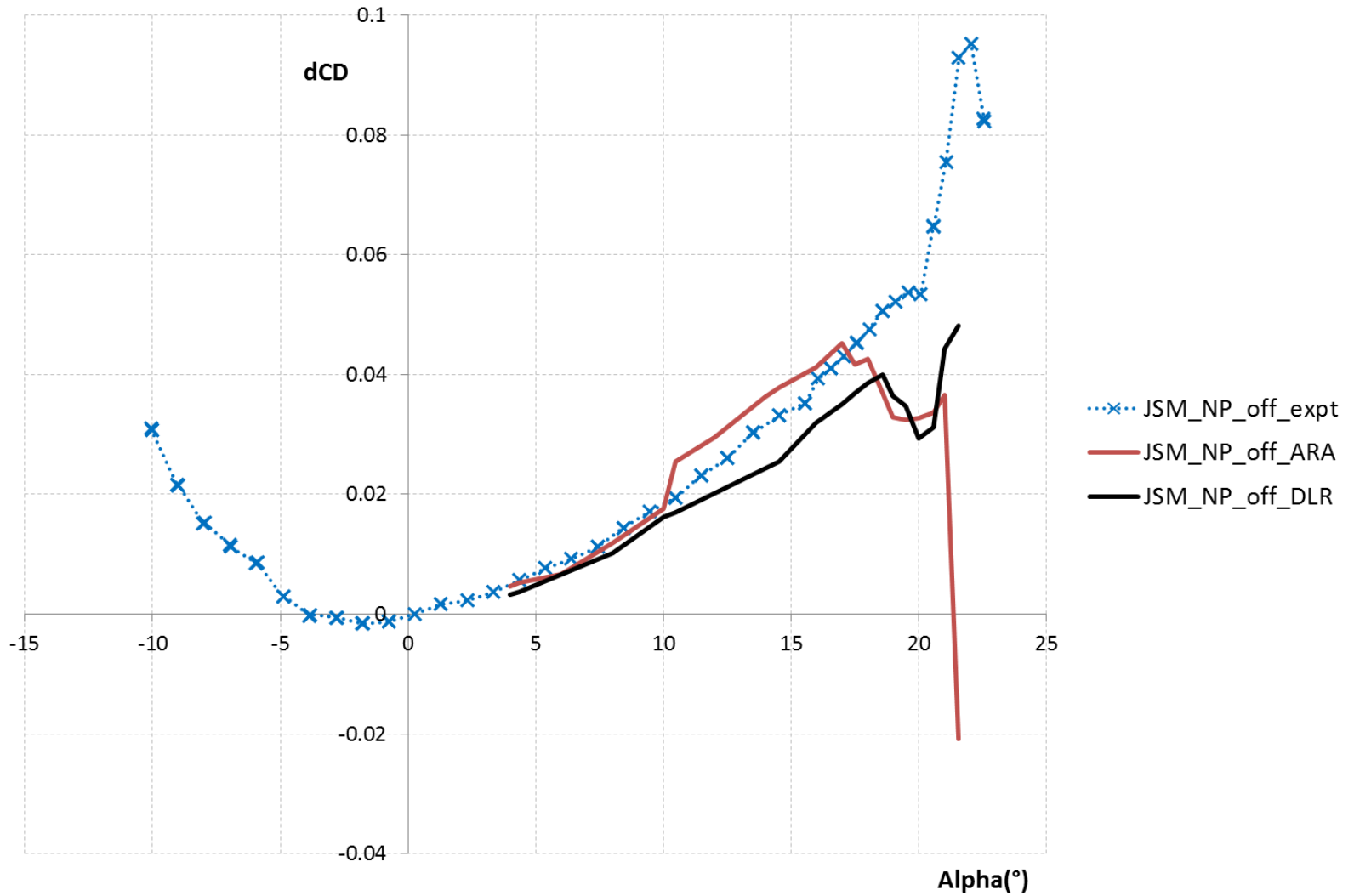


JSM with Nacelle-Pylon:

Variation of pitching moment with lift





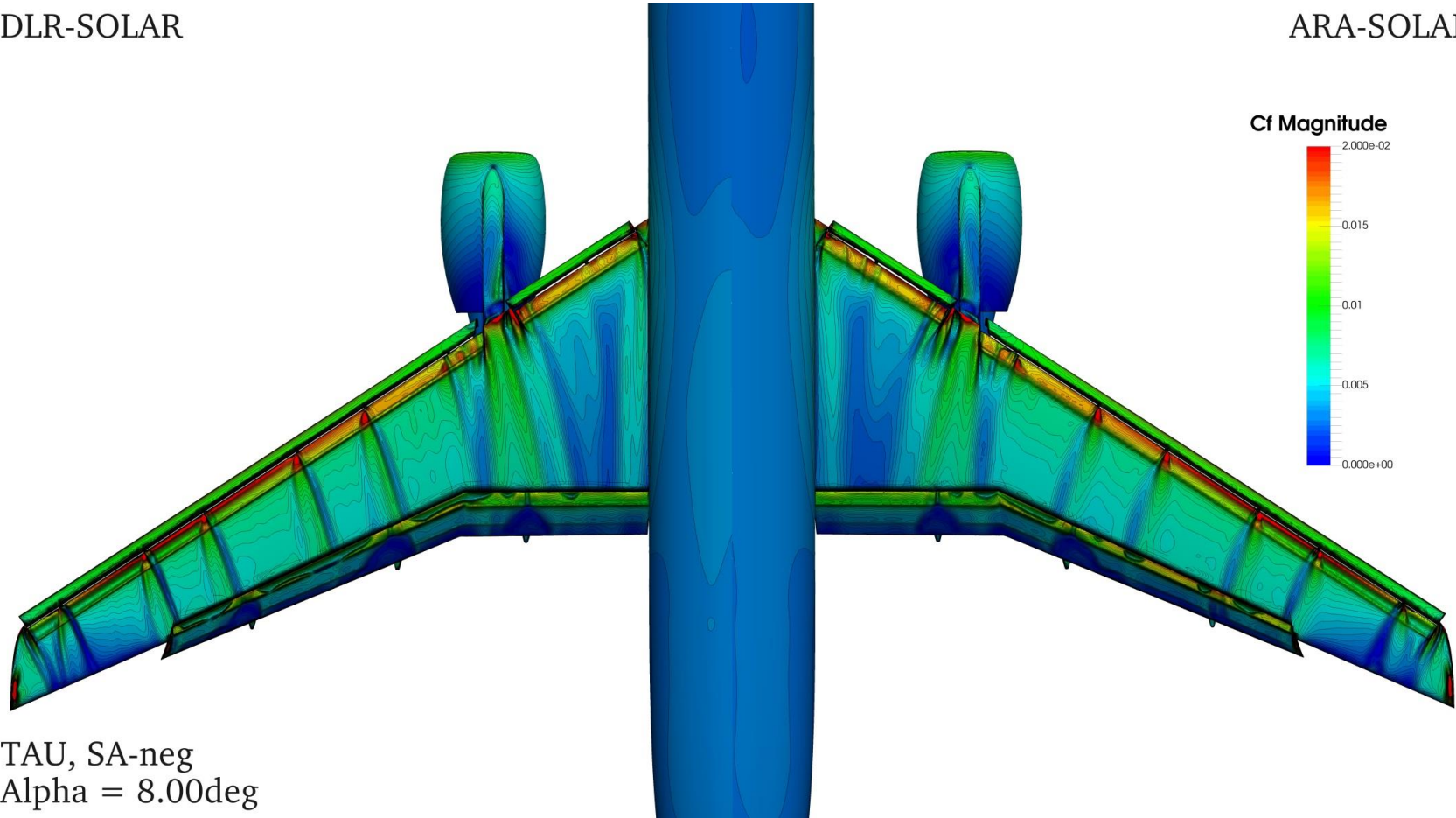


JSM with Nacelle Pylon: Skin friction



DLR-SOLAR

ARA-SOLAR



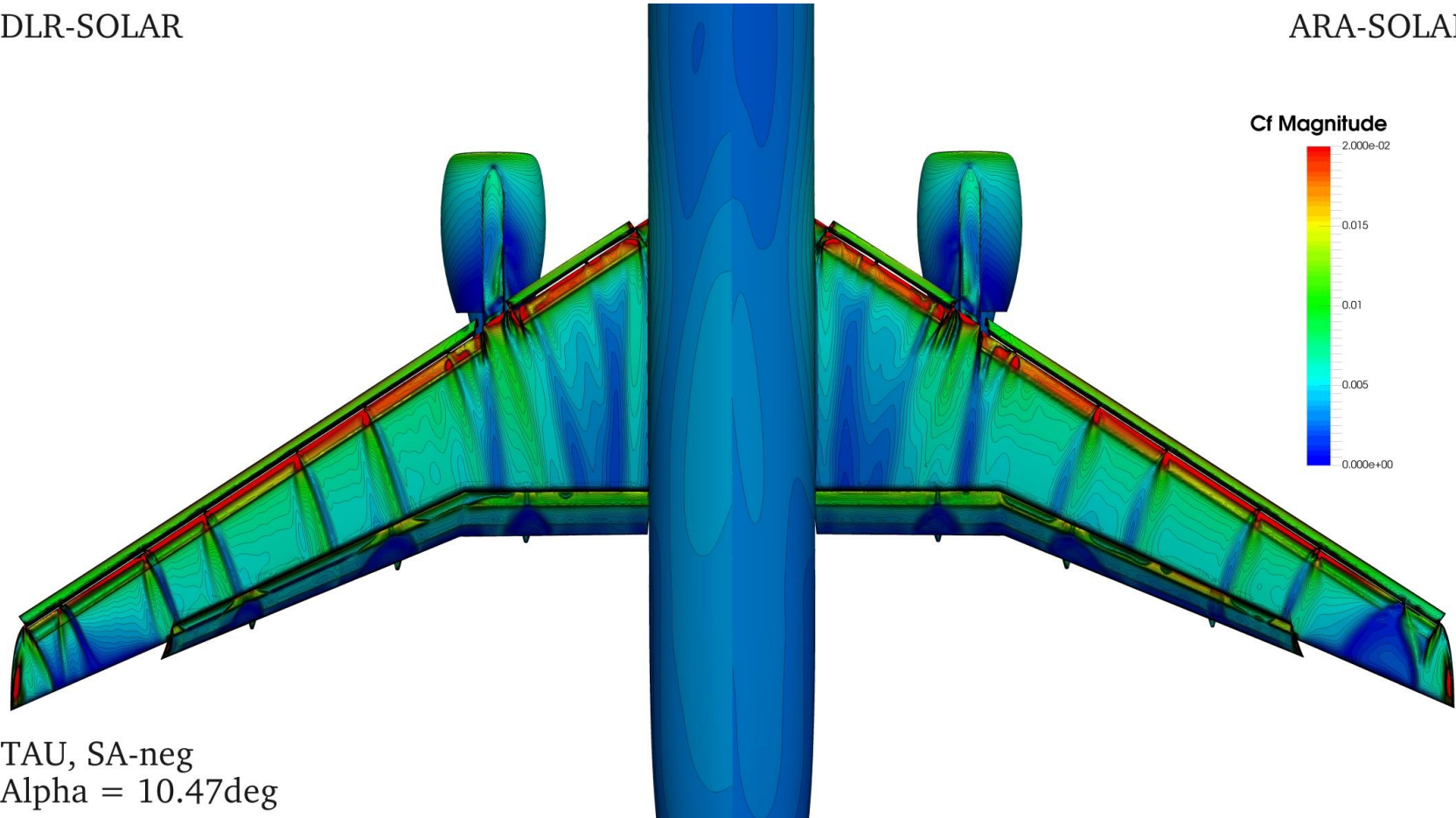
TAU, SA-neg
Alpha = 8.00deg

JSM with Nacelle Pylon: Skin friction



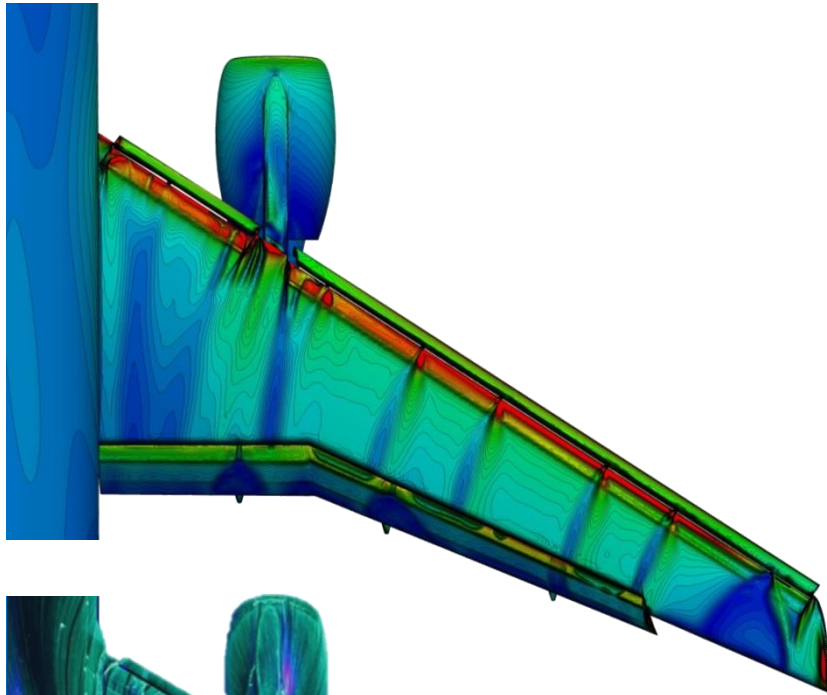
DLR-SOLAR

ARA-SOLAR

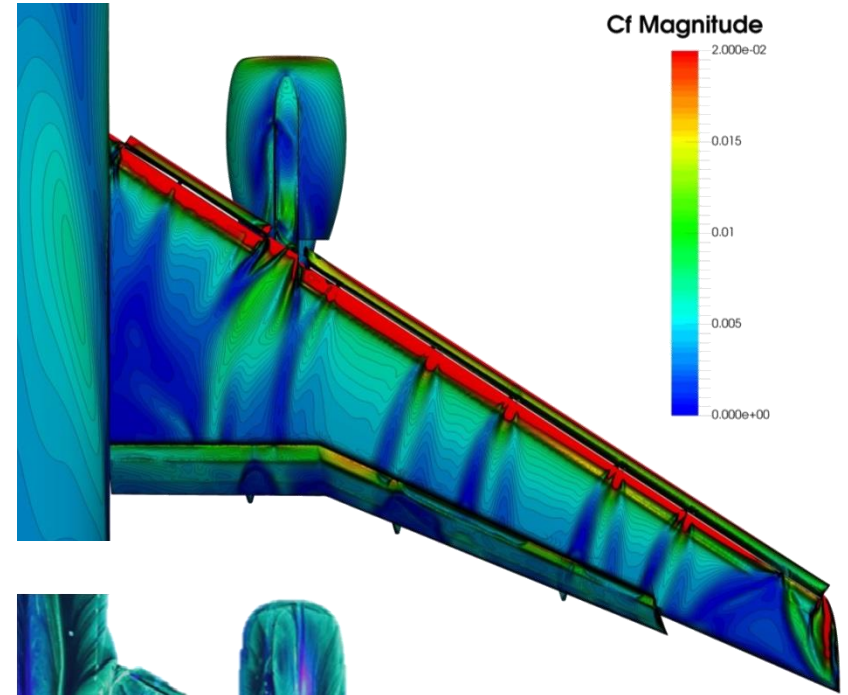


TAU, SA-neg
Alpha = 10.47deg

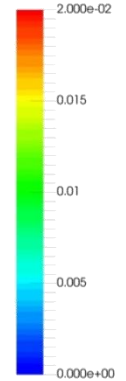
JSM Oilflow vs Cf contours: ARA-SOLAR



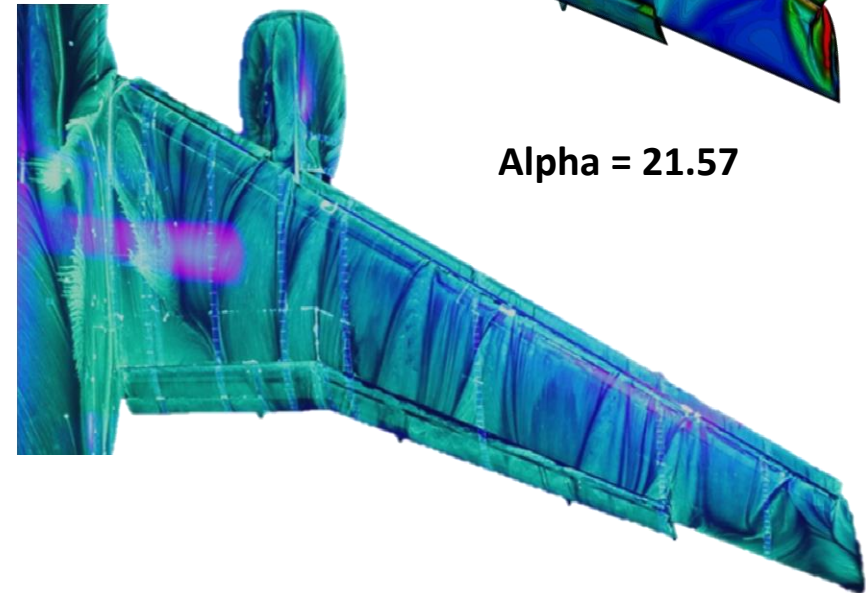
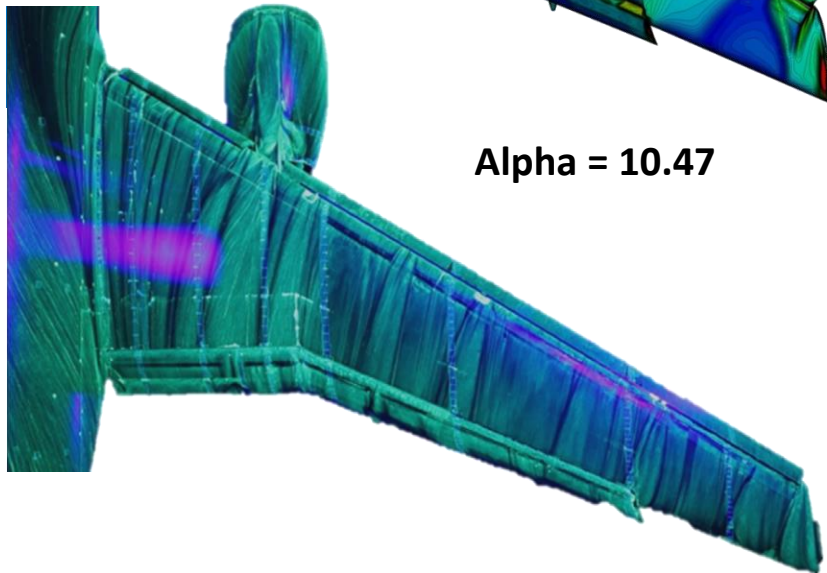
Alpha = 10.47



Cf Magnitude



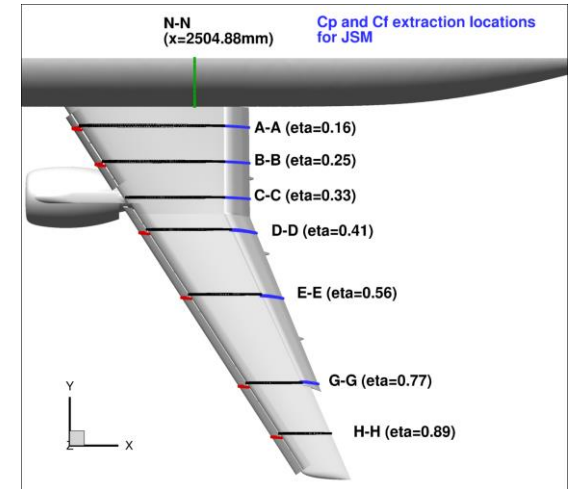
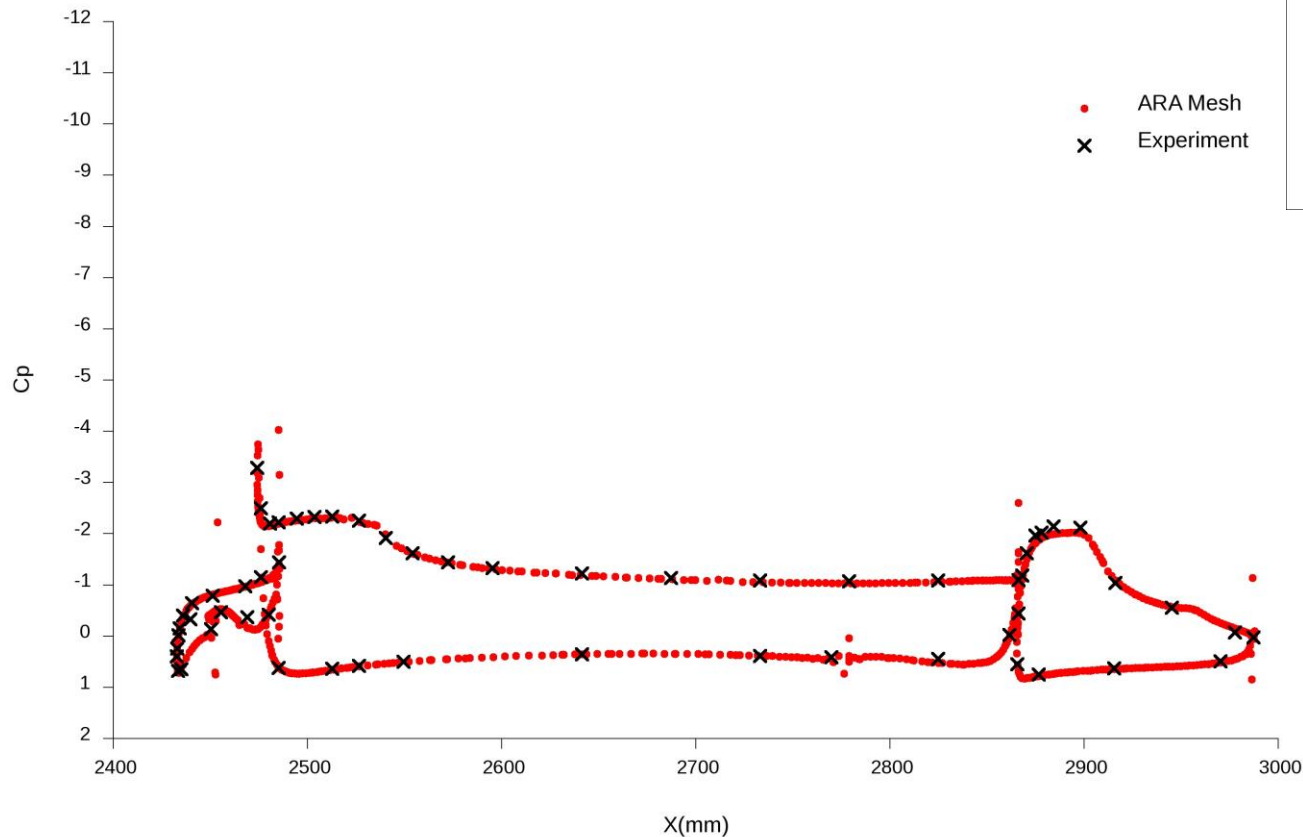
Alpha = 21.57



JSM Cp distributions: with nacelle pylon, E-E



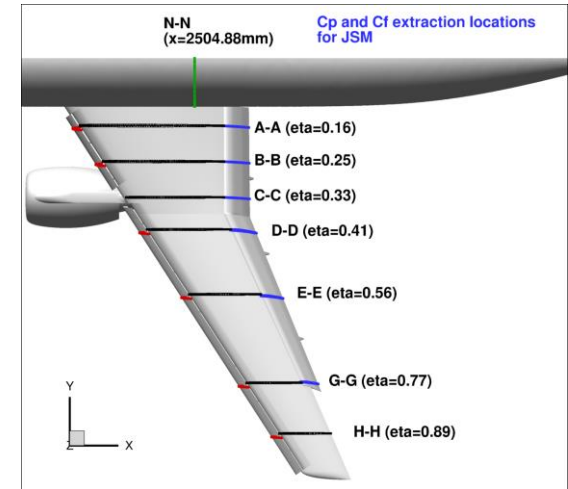
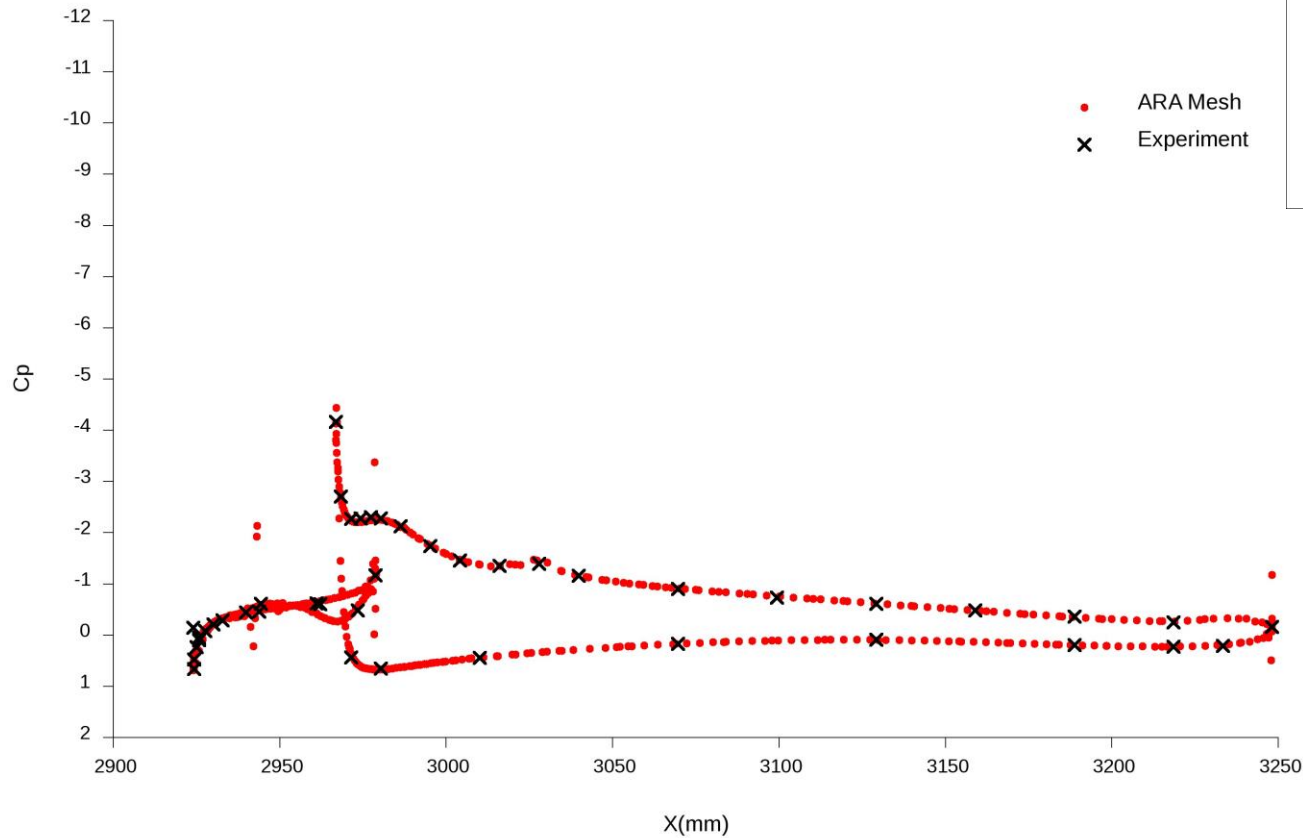
JSM with Pylon/Nacelle; Section E-E; $\alpha = 4.36^\circ$



JSM Cp distributions: with nacelle pylon, H-H



JSM with Pylon/Nacelle; Section H-H; $\alpha=4.36^\circ$



- Based on the JSM results from the ARA and DLR Solar meshes:
 - In terms of aerodynamic forces and moments, there is little difference between the two results, except results from the DLR mesh are giving the harder stall. The finer DLR mesh does not give a result which is clearly closer to experiment.
 - The DLR mesh generally produces better definition of the flow features, as would be expected and resolves smaller scale flow characteristics.
 - The ARA mesh gives an outer wing separation at a lower incidence than the DLR mesh and also than the experiment.
 - In terms of surface pressures, the ARA mesh produces a close comparison with experiment prior to flow separation. At an incidence where the CFD has separated on the outer wing but the experiment has not, the comparison deteriorates – as would be expected.
- In terms of routine use of its toolkit and current best practice for high-lift modelling – using affordable mesh size – ARA is encouraged by the quality of its predictions and sees no reason to significantly modify its best practice.



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